System size and energy dependence of ϕ meson production at RHIC

J. H. Chen[1,2] for the STAR Collaboration

[1]Nuclear Science division, Shanghai Institute of Applied Physics, CAS, Shanghai, 201800, China

[2]Department of Physics and Astronomy, University of California at Los Angeles, Los Angeles, CA, 90095, USA

Abstract. We present a system size and energy dependence of ϕ meson production in Cu+Cu and Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV and 200 GeV measured by the STAR experiment at RHIC. We find that the number of participant scaled ϕ meson yields in heavy ion collisions over that of p+p collisions are larger than 1 and increase with collision energy. We compare the results with those of open-strange particles and discuss the physics implication.

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1. Introduction

The primary aim of ultrarelativistic heavy-ion collisions is to produce and study a state of high-density nuclear matter called the quark-gluon plasma (QGP), the existence of which is supported by lattice QCD calculations [1, 2]. One of the predicted signals for QGP formation is the enhancement of strange particle production relative to that from light collision volume system, p+p or p+A system. In particularly, it's argued that due to the high production rate of $gg \rightarrow s\bar{s}$ in a QGP, strangeness production will be increased compared to that from a hadron gas [3]. The subsequent hadronization of these (anti)strange quarks results in a significant increase in strange particle production.

On the other hand, there is an additional effect in the small systems, e.g. p+p collisions, where a lack of available phase space caused a suppression of strangeness production [4, 5]. The so-called canonical suppression. However, the canonical suppression, by definition, doesn't apply to hidden-strange particles like ϕ meson. Therefore, by comparing the normalized yields of ϕ mesons with those of open-strange hadrons, one would be able to extract the information of production dynamics.

In this paper, we will present the preliminary transverse momentum (p_T) distributions of ϕ meson in Cu+Cu collisions at $\sqrt{s_{NN}} = 62.4$ GeV and 200 GeV. The ϕ yield in each p_T bin was extracted from the invariant mass distributions of $K^+ + K^-$ candidates after subtraction of combinatorial background estimated using event mixing technique. The charged Kaons were identified through their dE/dx energy loss in the

STAR Time Projection Chamber [6]. Details of the analysis can be found in Ref. [7]. The ϕ meson production in Au+Au collisions at the same energy will be compared to these measurements as well.

2. Results

2.1. ϕ meson production in Cu+Cu collisions

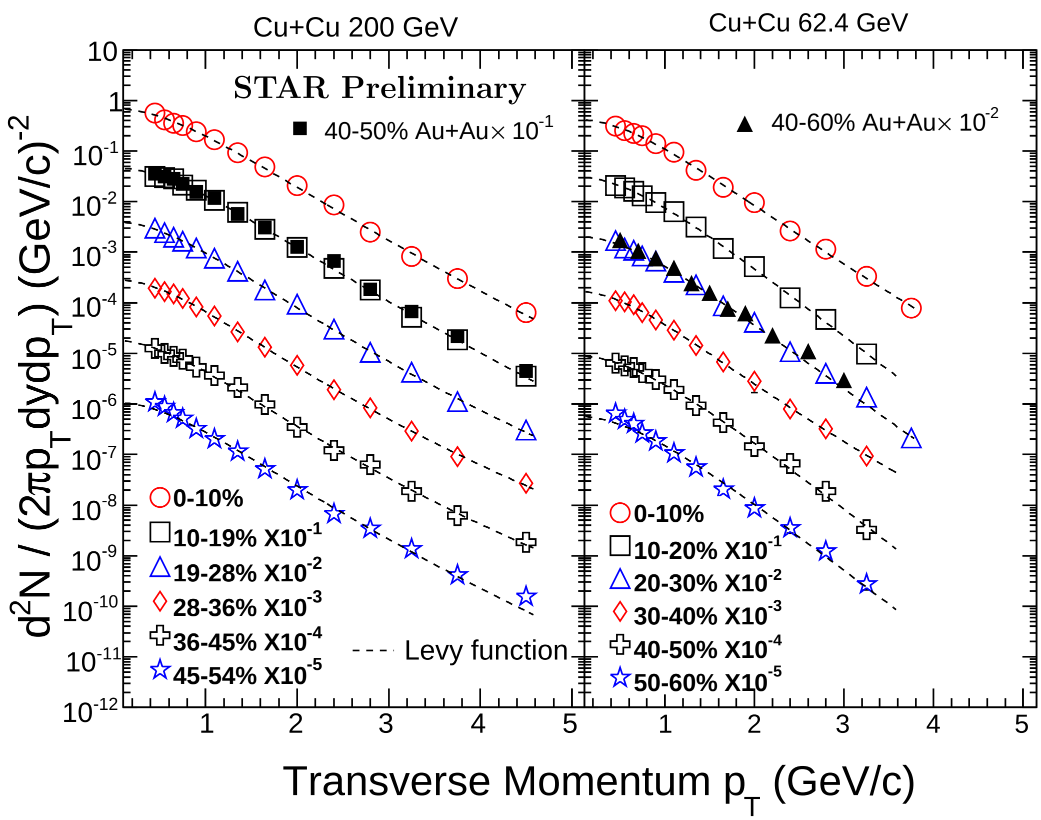

Figure 1. (color online) Preliminary midrapidity ($|y| < 0.5$) ϕ meson transverse momentum spectra for various centrality classes for Cu+Cu collisions at $\sqrt{s_{NN}}$ = 62.4 and 200 GeV. For comparison, results of ϕ meson spectra from 40-50% Au+Au collisions at 200 GeV and 40-60% Au+Au spectra at 62.4 GeV are also shown. The errors shown are statistical and systematic erros added in quadrature. They are found to be within the symbol size. The spectra are fitted to a levy function.

Figure 1 shows the ϕ meson spectra in 62.4 GeV and 200 GeV Cu+Cu collisions at various centralities. The distributions are well described by a levy function from central to peripheral collisions. For comparison, results of ϕ meson p_T distributions from 40-50% Au+Au collisions at 200 GeV and 40-60% Au+Au collisions at 62.4 GeV are shown in the figure as well. These centralities are chosen for similar number of participants ($\langle N_{part} \rangle$) at corresponding collisions energy. From the comparison, we find that, at a

given collision energy, the shape of the transverse momentum distributions and the yield of the ϕ meson are scaled by the number of participating nucleon.

2.2. Strangeness enhancement

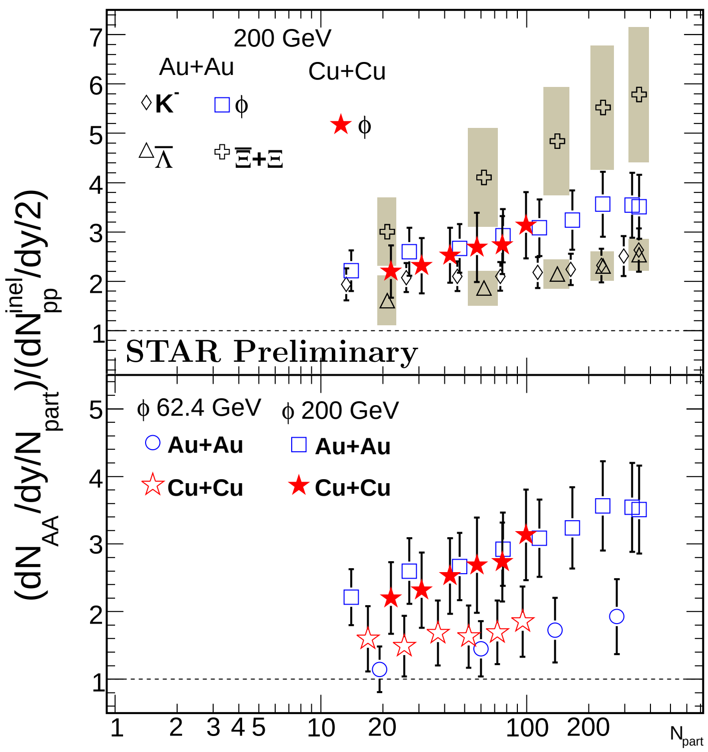

Figure 2. (color online) Upper panel: Ratio of yield of K^-, ϕ, $\bar{\Lambda}$ and $\Xi+\bar{\Xi}$ normalized to N_{part} in nucleus-nucleus collisions to corresponding yield in inelastic p+p collisions as a function of N_{part} at 200 GeV. Lower panel: Same as above for ϕ meson in Cu+Cu collisions at 200 and 62.4 GeV. The p+p collisions data from 200 GeV are from STAR [7] and 62.4 GeV from ISR [10]. The error bars shown are both statistical and systematic errors added in quadrature.

Figure 2 shows the strangeness enhancement factor, the N_{part} normalized ϕ yields from nucleus-nucleus collisions relative to that from p+p collisions, in Cu+Cu and Au+Au collisions. The results for published open-strange hadrons [8, 9] are also shown in the figure. As one can see, the enhancement factor for K^-, $\bar{\Lambda}$ and $\Xi+\bar{\Xi}$ increases with the number of strange valence quarks. The enhancement in these open strange hadrons increases with collision centrality and reaches its maximum at the most central collisions. The enhancement of the ϕ meson, however, deviates from the number of strange quark ordering. They are enhanced more than K^- and $\bar{\Lambda}$ but less than the $\Xi+\bar{\Xi}$. In spite of being different particle types (meson-baryon) and having different masses, the results for K^- and $\bar{\Lambda}$ are very similar in the entire centrality region studied. This rules out a baryon-meson effect as being the reason for the deviation of ϕ meson

from the number of strange quark ordering seen in Figure 2. The observed deviation is also not a mass effect as the enhancement in ϕ meson production is larger than $\bar{\Lambda}$.

The ϕ meson production is unlikely to be canonically suppressed due to its $s\bar{s}$ structure. The observed enhancement of ϕ meson production then is a clear indication of dynamical effect associated with medium density being responsible for strangeness enhancement in Au+Au collisions at 200 GeV. The observed enhancement in ϕ meson production being related to medium density is further supported by the energy dependence shown in the lower panel of Figure 2. The enhancement factor for ϕ mesons is larger at higher collision energy, a trend opposite to that predicted in canonical models for other strange hadrons.

3. Summary

In summary, we report the preliminary results of ϕ meson p_T spectra in Cu+Cu collisions at $\sqrt{s_{NN}}$=62.4 and 200 GeV. Earlier published ϕ results from Au+Au collisions are used for the purpose of discussions. At fixed energy, the ϕ mesons production seems to scaled with the N_{part}. The centrality and energy dependence of the enhancement in the ϕ meson production clearly reflects the enhanced production of s-quarks in a dense medium formed in high energy heavy-ion collisions. It then indicates that the source of enhancement of strange particle is related to the formation of a dense medium in high energy nucleus-nucleus collisions and cannot be solely due to canonical suppression of their production in smaller systems.

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